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**A METHODOLOGY FOR ESTIMATING DOG NOISE IN  
AN ANIMAL HOUSING FACILITY**

S. E. Sierens, M.E., H. A. Ingley, Ph.D., and E. L. Besch, Ph.D.,  
*University of Florida, Gainesville, Florida 32611*

**ABSTRACT**

A rectangular reverberation chamber was designed, constructed and calibrated for the experimental measurement of the sound power level (acoustic power) of a dog. Calibration of the chamber consisted of comparing the acoustic power measured for a random noise source in the chamber with that for the identical source in a free field environment. Data from dogs indicate that barking noise can be modeled as a square wave pattern with short duration and peak sound power levels in the 500 Hz octave band. A-weighted sound pressure levels of up to 114.7 dBA were absorbed, indicating a potential concern for both animals and man chronically exposed to such environments.

**INTRODUCTION**

Although noise has been recognized as an important parameter for the research animal bioenvironment (1,2,3), little scientific evidence is available from which exposure levels for animals may be specified (4). Previous recommendations on acceptable noise levels for animals (3) were based on animal exposures to a minimum noise intensity for 40 hours per week. Dog barking appears to be a primary cause of high noise in an animal facility (2,5), but no apparent attempts have been made to quantitate the dog as a noise source or to characterize the dog's sound power levels. Further, little information is available concerning permissible noise exposures of humans in animal facilities or whether existing levels exceeded those specified by OSHA (6). Such information not only would be useful in estimating noise levels but also would allow for appropriate acoustic designs in existing or new facilities. These considerations led to the research reported here.

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## MATERIALS AND METHODS

### Reverberation Chamber

Based on preliminary measurements in a typical animal facility which indicated noise levels associated with barking dogs were predominantly in the frequency range of 250 Hz to 4 KHz, a lower limiting frequency of 250 Hz was selected for the reverberation chamber design (7). The dimensions of the chamber were selected based on two criteria:

- 1) the interior volume of the chamber should be greater than or equal to  $4\lambda^3$ , where  $\lambda$  is the corresponding wavelength for the lower limiting frequency (8);
- 2) the chamber dimensions of length, width, and height should possess ratios of 1.0; 1.259; 1.587, respectively (8).

The chamber (Fig. 1) was constructed of wood with a glazed tile interior wall finish. The glazed tile provided a hard, reflective interior surface necessary to produce a diffuse sound field within the chamber. To further enhance this diffuse quality of the chamber, irregular geometric shapes were constructed on several of the walls. The walls were also splayed so that no two walls were parallel. The final chamber interior surface area (S) was 31.73 m<sup>2</sup> (341.5 ft<sup>2</sup>); the volume (V) was found to be 9.82 m<sup>3</sup> (346.8 ft<sup>3</sup>).

### Chamber Calibration

The schematic (Fig. 2) identifies instrumentation used in chamber calibration. Eight microphone positions were monitored for each of ten speaker locations in the chamber to provide data from which to select an optimum source and microphone position. A noise generator (Bruel and Kjaer, Type 1402), a 100 watt amplifier and a sound driver provided the random noise source. A microphone (General Radio, Type 1560-P6) and magnetic data recorder (General Radio, Type 1525-A) were used to monitor the noise levels in the chamber. All data were analyzed on an audio frequency spectrometer (Bruel and Kjaer, Type 2112) and graphic level recorder (Bruel and Kjaer, Type 2305). The reverberation time (T<sub>60</sub>) of the chamber was determined for several octave band frequencies.

Reverberation chamber data were compared with data from a free field environment to verify the

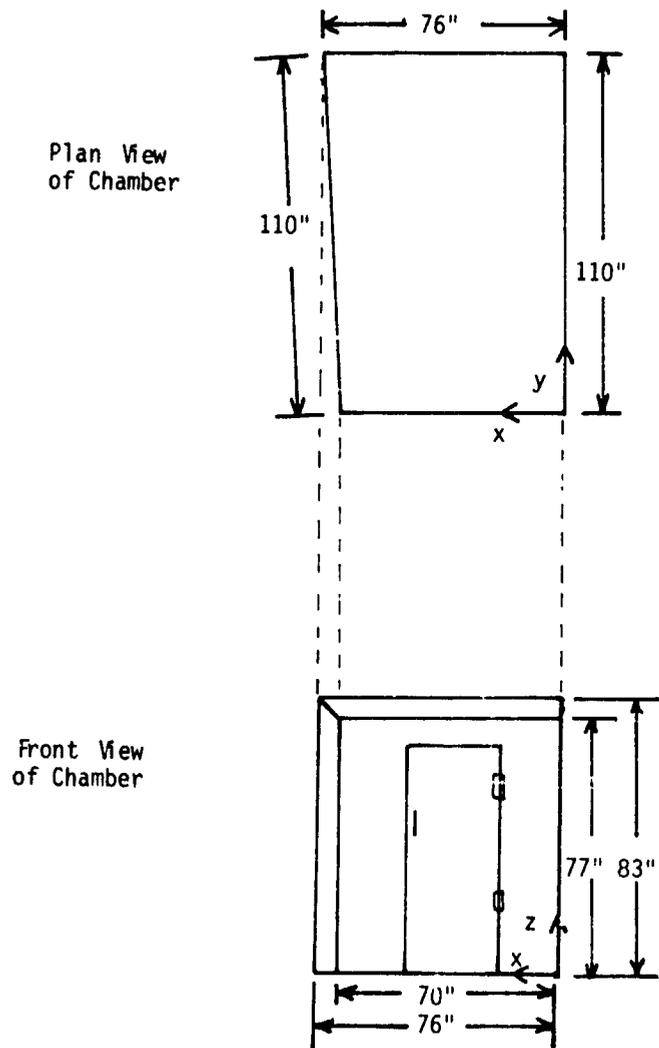


Figure 1. Coordinate System and Reference Axes for Location of Speaker and Microphone Positions, Reverberant Field

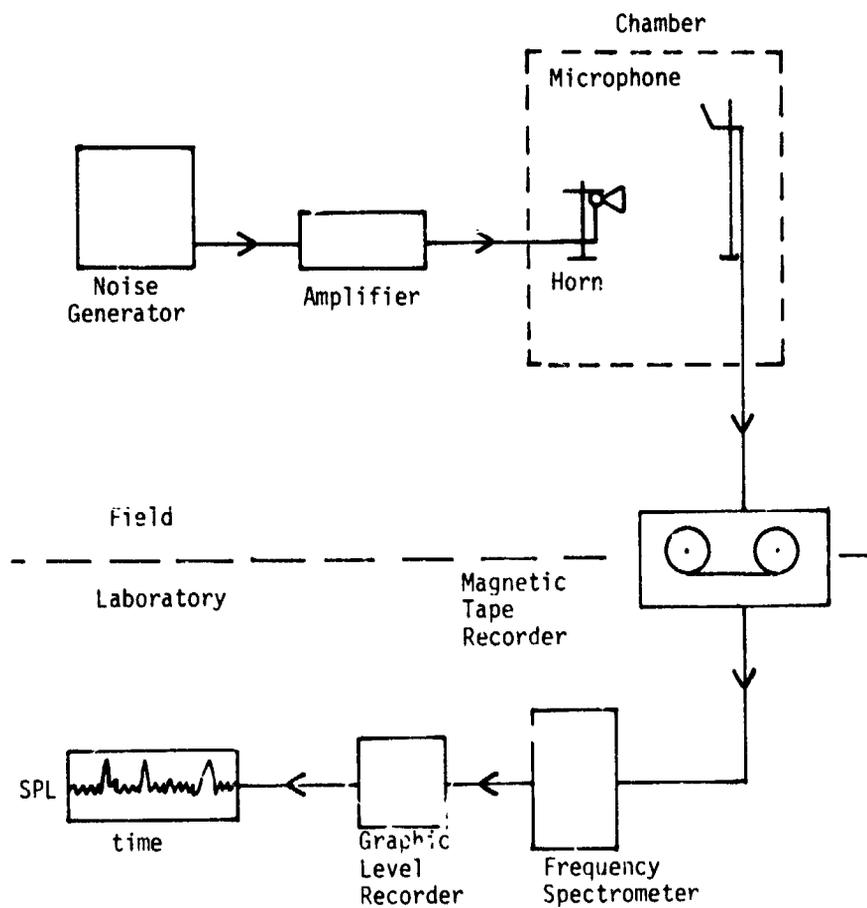


Figure 2. Schematic of Instrumentation Used in Reverberation Time Measurements

reliability of results obtained in the chamber. Although free field measurements usually provide more accurate means of determining sound power levels for a noise source, it is very difficult to use such a field to determine acoustic power levels for laboratory animals.

### Animals

A male, adult German Shepherd dog was acclimated to the chamber for a period of 14 days. A microphone was placed in the chamber at the optimum position determined during the calibration runs. The dog was placed in one corner of the chamber which appeared to be a satisfactory location for the sound power level determinations. Dog barks were recorded on magnetic tape for a period of 15 minutes.

From analyses of fifty barks recorded during the test period, peak sound pressure levels, duration times, and rise times were recorded for each bark. Using the sound pressure level and room response data, average sound power levels were calculated for octave bands centered at 250 Hz, 500 Hz, 1 KHz, 2 KHz, 4 KHz, 8 KHz, and 16 KHz.

### Calculations

Assuming that the chamber would provide a diffuse sound field, equation (1) was used to determine sound power levels (PWL) for the sound source placed in the room:

$$\text{PWL} = \overline{\text{SPL}} + 10 \text{ Log } V - 10 \text{ Log } T_{60} + 10 \text{ Log } \left( 1 + \frac{S\lambda}{8\lambda} \right) - 13.5 \text{ (dB)} \quad (1)$$

where PWL = sound power level, dB, in frequency band of interest

$\overline{\text{SPL}}$  = average sound pressure level (usually from several microphone positions), dB, in frequency band of interest

V = total volume of test room, m<sup>3</sup>

T<sub>60</sub> = reverberation time of test room in frequency band of interest, sec.

S = interior surface area of room, m<sup>2</sup>

λ = wavelength of center frequency of test band, m

The volume (V) and interior surface area (S) were determined from the dimensions of the reverberation chamber. The reverberation time (T<sub>60</sub>) and average

sound pressure level ( $\overline{SPL}$ ) were determined experimentally.

## RESULTS

Data (Table 1) from several free field environments compared favorably with data taken in the reverberation chamber utilizing the same sound power source operating at identical power settings. In most comparisons of the free field to reverberant field measurements of sound power levels, the percent error did not exceed 5%.

Data from the barking dog (Table 2) were consistent and reproducible and the range of sound pressure levels in any octave band appeared to be less than 20 dB. The dog appears to have the widest range of sound pressure levels in the lower frequencies with a decreasing range at increasing frequencies. For example, at 1 KHz the range of sound pressure levels was 13 dB (102 to 115) while at 16 KHz the range was 4 dB (68 to 72). The standard deviations in sound pressure level varied from 3.7 dB at 2 KHz to 1.3 dB at 16 KHz. The 95% confidence intervals were extremely small, ranging from 0.4 dB at 16 KHz to 1.0 dB at 2 KHz and 4 KHz, due in part to the large sample size. The sound pressure level in the 500 Hz octave band was within 0.5 dB of the overall sound pressure level (All Pass) indicating that the sound pressure levels in the remaining octave bands contribute little to the total sound level. The A-weighted sound pressure levels measured in the reverberation chamber ranged from 100-119 dBA, with an average A-weighted sound pressure level of 114.7 dBA.

The slope and general pattern of the decay curves (room response) from an interrupted noise source were virtually identical to the slope and pattern of the decay portion of the dog barks. Thus, the barking pattern can be treated as a square wave pattern with a very steep rise time (0.1 second) and a duration of about 0.05 second. These curves - spaced about 1.5 seconds from one another - have peak levels that vary with the octave band (Table 1).

Figure 3 illustrates the sound power level frequency distribution for the dog bark, calculated from equation (1) with appropriate substitutions. Data points of octave bands above 500 Hz appear to be linear with an average slope of minus 10.1 dB per octave. The single exception is at 8 KHz where a

TABLE 1  
SUMMARY OF AVERAGE SOUND POWER LEVELS  
(PWL) FOR CALIBRATION SOURCE dB

Notation: ○ Spherical Free Field, △ Hemispherical Free Field, Position 2  
▽ Hemispherical Free Field, Position 1, □ Reverberant Field

Power Setting (1)

All Pass	A	Octave Band Center Frequency							
		250	500	1000	2000	4000	8000	16000	
○ 106.4	106.6	83.2	98.2	101.3	103.2	103.2	103.2	87.2	72.0
△ 109.6	110.4	80.6	95.0	100.0	106.2	105.0	105.0	99.7	77.0
▽ 106.4	107.1	77.9	93.9	98.8	102.8	101.4	101.4	94.7	73.5
□ 108.6	107.7	81.4	97.3	100.8	104.2	100.5	100.5	91.9	72.5
PWL, ○, △, ▽, □	108.7	81.1	96.1	100.1	104.3	102.2	102.2	96.3	74.6
% error	.83	.37	1.25	.69	.09	1.7	1.7	4.6	2.8

Power Setting (2)

All Pass	A	Octave Band Center Frequency							
		250	500	1000	2000	4000	8000	16000	
○ 117.3	117.7	94.5	108.5	112.3	113.9	107.3	107.3	97.5	77.6
△ 121.7	122.2	93.2	107.1	112.0	117.7	116.4	116.4	110.2	92.9
▽ 119.7	120.1	91.9	106.5	112.3	115.5	114.3	114.3	107.1	88.6
□ 120.6	119.6	94.3	109.0	112.8	115.9	110.2	110.2	102.8	82.6
PWL, ○, △, ▽, □	119.9	93.4	107.4	112.2	115.9	116.1	116.1	107.3	89.6
% error	.58	.96	1.5	.53	0	5.1	5.1	4.2	7.8

TABLE 2

MEAN ( $\pm$  SD) SOUND PRESSURE LEVELS (SPL) FOR THE GERMAN SHEPHERD DOG  
(In all instances, 50 barks were analyzed)

	All Pass	A	Octave Band Center Frequency, Hz						
			250	500	1000	2000	4000	8000	16000
SPL, dB	119.3	114.7	96.4	118.8	110.5	100.5	90.2	84.5	69.6
S.D., dB	2.3	2.9	2.5	2.2	2.9	3.7	3.5	2.4	1.3
95% Confidence Interval for the Mean	$\pm 0.6$	$\pm 0.8$	$\pm 0.7$	$\pm 0.6$	$\pm 0.8$	$\pm 1.0$	$\pm 1.0$	$\pm 0.7$	$\pm 0.4$
High	123	119	102	123	115	107	97	90	72
Low	112	100	93	113	102	90	82	79	68

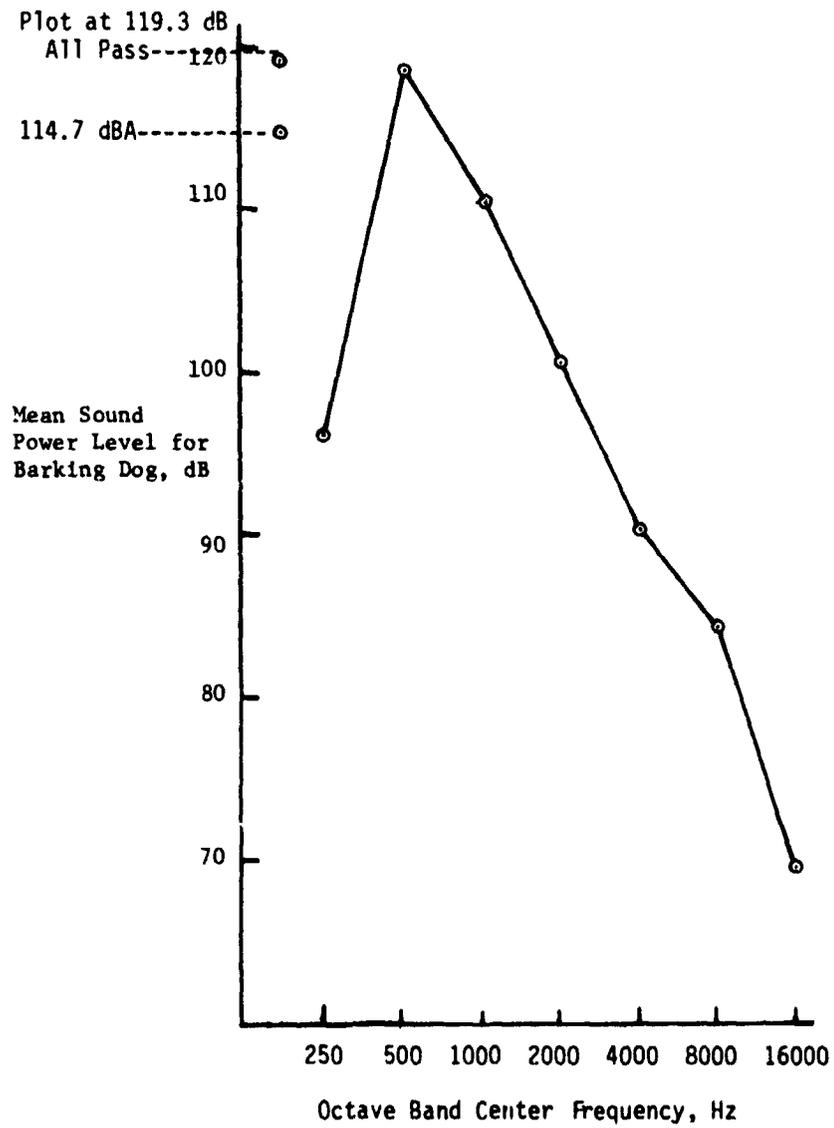


Figure 3. Sound Power Level (PWL) versus Frequency for Dog

slight deviation from the linear decay is noted. From 250 Hz to 500 Hz the rate of increase was about twice the rate of decrease from 500 Hz to 16 KHz, or about 22.7 dB per octave. Analysis of the three 1/3 octave bands in the 500 Hz octave band indicates the "characteristic frequency" is in the range of 447 to 562 Hz for this particular dog.

#### DISCUSSION

Our reverberation chamber appears to have provided a reliable tool for determining sound power levels for the laboratory dog. The data obtained from one barking dog resulted in highly reproducible calculations of sound power levels. However, the generalized use of these data may have limited value for immediate applications for acoustic problems in animal housing facilities. Barking noise from more breeds needs to be analyzed. Other dogs may provide significantly different sound power level - frequency profiles, although sound levels are expected to reach the same magnitude as reported here.

In order to completely evaluate the effects of barking dog noise on the animal itself or the humans involved with the animals, further investigations for establishing the A-weighted noise exposure and the time pattern of the dog barks will be necessary. The average A-weighted noise level of 114.7 dBA reported here is an indication in itself that there is a potential concern for both man and animals.

Data from Table 2 and Figure 3 may be used to predict the sound pressure levels in any environment through the use of standard acoustical relationships (8). For example, equations similar to equation (1) may be rearranged to solve for the average sound pressure level in any given environment if the sound power level of the noise source and the acoustical characteristics of the room are known. Further, with additional sound power level data, noise levels in an animal room of known design may be estimated prior to construction. These data also would be invaluable in solving noise problems for existing facilities.

#### ACKNOWLEDGMENT

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